Plant Science & Food Safety Research

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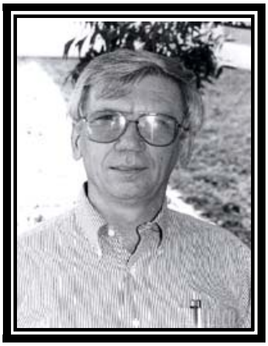
Mission

The mission of the Plant Science & Food Safety Research unit is to increase the yields, quality, safety, and desirability of agronomic and horticultural plants grown on salt affected soils. The unit is charged with evaluating the tolerance of plant species, developing an understanding of the interactive effects of salinity and environmental factors on plants, elucidating the morphological, biophysical, biochemical and molecular mechanisms of salt tolerance and salt injury, developing a basis for genetic increases in salt tolerance, and developing control strategies to prevent transmission of pathogens from animal waste operations to food-producing animals, agricultural crops, surface and ground waters. These principles are to be integrated into crop response models, and soil/water transport models which can be used to recommend management practices and systems that improve agricultural productivity, food safety, and environmental protection.

PLANT SCIENCE & FOOD SAFETY RESEARCH STAFF

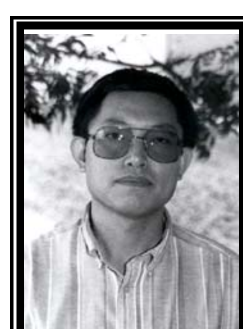


MICHAEL C. SHANNON, B.S., Ph.D., Laboratory Director, Supervisory Research Geneticist for Plant Science & Food Safety Research
Genetic screening for crop Tolerance to soil salinity; heritable characteristics of plant uptake and exclusion-of ions for soils and irrigation waters.

CATHERINE M. GRIEVE, B.S., Ph.D., Plant Physiologist for Plant Science & Food Safety Research.
Effect of water quality on morphological development of small grain crops. Plant response to irrigation water composition. Identification of halophytic crops for drainage water reuse systems.

CLYDE WILSON, B. A., M. S., Ph. D., Research Plant Physiologist for Plant Science & Food Safety Research.
Biochemical and biophysical mechanisms underlying adapation to saline environments; photosynthetic and stomatal responses to saline irrigation water; bioenergetic and membrane changes due to salt stress.

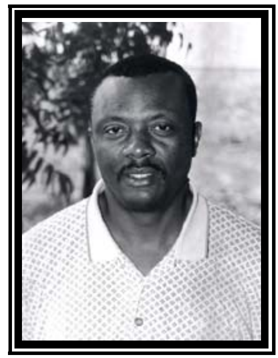
DONG WANG, B.S., M.S., Ph.D., E.I.T., Soil Scientist for Plant Science & Food Safety Research.
Drip, sprinkler, furrow irrigation systems; processes and mechanisms attributing to soil and water salinity; environmental biophysical factors affecting plant growth under saline environment; heat and mass transfer in the soil-water-plant-atmosphere continuum.



PLANT SCIENCE & FOOD SAFETY RESEARCH STAFF

FRANCIS N. DALTON, B.S., M.S., Ph.D., Research Soil Scientist for Plant Science & Food Safety Research.
Simulation of coupled water and ion uptake by plant roots as it relates to plant response in saline environments; development of environmentally independent dynamic salinity stress index, SSI, Instrumental techniques for in-situ measurement of soil water content/electrical conductivity; soil/plant water energetics, root extent/distribution.

A. MARK IBEKWE, B.S., M.S., Ph.D., Research Microbiologist for Plant Science & Food Safety Research.
Detection, survival, transport, and reduction of human pathogens in the environment. Primary research focus in the area of Plant-Microbe interactions and the role of microorganisms in the ability of soil to recover from degradation after disturbance or response to stress.



SCOTT BRADFORD, B.S., M.S., Ph.D., Soil Scientist for Plant Science & Food Safety Research.
Detection, survival, transport, and reduction of human pathogens in the environment. Multiphase flow and transport of organic and inorganic contaminants in soil and aquifer systems.

MICROPORE PROCESSES, MEASUREMENTS AND MODELS RELATED TO ROOT WATER EXTRACTION AND PLANT RESPONSE IN SALINE ENVIRONMENTS

F.N. Dalton

The ability to correlate the dynamic behavior of macroscopic properties of a soil-plant system in terms of fundamental micropore processes provides significant insights to the predominant physical phenomena governing plant response in saline environments. This paper shows that with respect to salinity, the onset of yield reduction is fundamentally related to the dynamics pore water ion transport to root xylem tissue and not, as it traditionally assumed, to the osmotic potential of the pore water. Besides micropore processes and biophysical transport properties of roots, ion transport is shown to be controlled by climatic variables that simultaneously effect water use and growth. Concepts to be revisited include the significance of the relative root surface area that is in contact with liquid phase pore water and why matric and osmotic potentials cannot be assumed to be additive with respect to yield reduction.

Agronomy Abstract p. 174, 1999.

CROP RESPONSE AND MANAGEMENT OF SALT-AFFECTED SOILS

L.E. Francois† and E.V. Maas

Salinity is a major factor reducing plant growth and productivity throughout the world. Approximately 10% of the world's 7 x 10^9 ha arable land surface consists of saline or sodic soils. The percentage of cultivated lands affected by salts is even greater. Of the 1.5 x 10^9 ha cultivated lands, 23% are sonsidered saline and another 37% are sodic. Although the data are tenuous, it has been estimated that one-half of all irrigated lands (about 2.5 x 10^8 ha) are seriously affected by salinity or waterlogging. Historically, soil salinity contributed to the decline of several ancient civilizations. Despite the advanced management technologies available today, salinization of millions of hectares of land continues to reduce crop production severely in the United States and worldwide. The National Academy of Sciences includes salinization of soils and waters as one of the leading processes contributing to a world-wide biooogical catastrophe.

Sustained and profitable production of crops on salt-affected soils is possible if appropriate on-farm management decisions are made. To be successful, growers require an understanding of how plants respond to salinity, the relative tolerances of different crops and their sensitivity at different stages of growth, and how different soil and environment conditions affected salt-stressed plants. This chapter discusses the effect of soil and water salinity on agronomic and horticultural crop plants, presents data on the tolerance of crops to salinity, and considers consequences of various cultural and management practices on crop yield responses.

In: Handbook of Plant and Crop Stress (M. Pessarakli, Ed.), Marcel Kekker, Inc., New York, Chapt. 8, pgs 169-201, 1999.

† Deceased

SCREENING EUCALYPTUS CLONES FOR SALT TOLERANCE

C.M. Grieve, M.R. Guzy, J.A. Poss and M.C. Shannon

Agroforestry plantations offer environmentally-acceptable strategies for the reuse of saline drainage waters. Tree species suitable for use in such systems must be selected for survival and sustained growth under highly saline conditions. In this screening trial, four clones of *Eucalyptus camaldulensis* Dehn. (4543, 4544, 4573, and 4590) and one clone of *E. rudis* Endl. (4501) were grown in greenhouse sand cultures irrigated with sodium sulfate-dominated waters. Solution compositions were prepared to simulate saline drainage waters typically found in the San Joaquin Valley of California. Electrical conductivities of the solutions ranged from 2 to 28 dS m^{-1}. Treatments were replicated three times. All plants survived and were harvested after 7 weeks under saline treatment. Plant height was measured weekly and shoot biomass was determined at final harvest. The salinity levels that resulted in a 50% reduction in biomass production (C_{50}) were 16.4 (4573), 17.1 (4543), 17.7 (4544), 29.0 (4590), and 30.0 dS m^{-1} (4501). Over the range of salinities from 4 to 20 dS m^{-1}, clones 4501, 4590, and 4573 generally maintained higher relative growth rates (RGR) than did clones 4544 and 4543. However, at the highest salinity, RGR of clones 4501, 4544 and 4573 were significantly greater than those of clones 4543 and 4590. Assessed on the basis of biomass production, clones 4501 (*E. rudis*) and 4590 (*E. camaldulensis*) showed exceptional potential for use in agroforestry systems where the saline drainage waters are sodium sulfate-dominated.

HortScience 34:867-870, 1999.

SALINITY EFFECTS ON GROWTH, SHOOT-ION RELATIONS, AND SEED PRODUCTION OF *LESQUERELLA FENDLERI*

C.M. Grieve, M.C. Shannon and D.A. Dierig

Lesquerella [*Lesquerella fendleri* (Gray) S. Wats.] was grown in outdoor sand cultures irrigated with waters designed to simulate saline drainage effluents present in the San Joaquin Valley of California, and compositions that would result from further concentration of the water. These waters are typically high in Na^+, SO_4^{2-}, Cl^-, Mg^{2+}, and Ca^{2+}, predominating in that order. Salts were added to complete nutrient solutions to give eight salinity treatments with electrical conductivities (EC) of 3, 6, 9, 12, 15, 18, 21, and 24 $dS \cdot m^{-1}$. Treatments were replicated three times. Vegetative growth, seed yield, leaf- and stem-ion content were determined. Plant survival was reduced when salinity exceed 15 $dS \cdot m^{-1}$ and continued to decrease over time. The few survivors in the 24 $dS \cdot m^{-1}$ treatment were rescued and eventually grown in crossing blocks under nonsaline conditions. The divalent cations, Ca^{2+} and Mg^{2+}, were strongly accumulated in the shoots and were preferentially partitioned to the leaves rather than the stems. Chloride partitioning followed a similar pattern. In contrast, Na^+ and K^+ were more uniformly distributed between leaf and stem tissues. Leaf-Ca and-K decreased with increasing salinity, whereas leaf-Na and -Cl increased. Biomass production was reduced by 50% at 14.9 $dS \cdot m^{-1}$. Leaf area decreased consistently from a mean of 950 to 65 cm^2 per plant as irrigation water salinity increased from 3 to 21 $dS \cdot m^{-1}$. Average seed yield per plant was ~2 g in the 3, 6, 9, and 18 $dS \cdot m^{-1}$ treatments and 3 g at 12 and 15 $dS \cdot m^{-1}$.

Book: IN: J. Janick (ed.), Perspectives on New Crops and New Uses, Part III, p. 239-243, ASHS Press, 1999. Proc. 4th Nat'l. Symp., AAIC, "New Crops and New Uses Biodiversity and Agricultural Sustainability, Phoenix, AZ, Nov. 8-11, 1998.

ION ACCUMULATION AND DISTRIBUTION IN SHOOT COMPONENTS OF SALT-STRESSED EUCALYPTUS CLONES

C.M. Grieve and M.C. Shannon

Four clones of *Eucalyptus camaldulensis* Dehn. (4543, 4544, 4573, and 4590) and one clone of *E. rudis* Endl. (4501) were grown in greenhouse sand cultures irrigated with sodium-sulfate dominated waters. Electrical conductivities of the solutions were 2, 12, and 28 dS m^{-1}. Treatments were replicated three times. Mechanisms of differential salt tolerance based on ion uptake and distribution patterns in above-ground components were studied in saplings grown under treatment for 7 weeks. Potassium and Mg^{2+} were preferentially accumulated in the youngest leaves in the upper portion of the canopy, whereas Ca^{2+} was retained in the older leaves. At the lowest salinity level, phosphorus was translocated to the youngest leaves, but was more uniformly distributed in the canopy as salinity increased. Leaf- and stem-Cl^- levels tended to be higher in all clones grown at 2 dS m^{-1} than at 28 dS m^{-1}. The clones could be separated into two distinct groups by significant differences in leaf-ion relations and, to a lesser degree, stem-ion content. Group 1, clones 4543, 4544, and 4573, were more active Na^+-excluders and accumulated more Ca^{2+} and Cl^- than clones 4501 and 4590. Clones in group 2, 4501 and 4590, were relatively active Na^+ accumulators under low salinity, but apparently possessed some mechanism for restricting leaf-Na^+ that was activated as salinity increased. In response to the 28 dS m^{-1} treatment, the efficiency of K^+ uptake relative to Na^+ by both groups was unusually high. At this salinity level, mean K^+:Na^+ selectivity coefficients were 315 and 130 for the leaves of clones of groups 1 and 2, respectively.

Amer. Soc. Hort. Sci. 124:559-563, 1999.

EFFECT OF SALINE IRRIGATION WATER COMPOSITION ON SELENIUM ACCUMULATION BY WHEAT

C.M. Grieve, D.L. Suarez and M.C. Shannon

Trace amounts of selenium are essential for animal and human nutrition. However, the optimum concentration range is very narrow and outside of this range deficiencies or toxicities can occur. Potentially harmful levels of selenium in soils and irrigation waters have been reported in regions where salinity is also a hazard. This study was conducted to determine the effects of irrigation water composition and salinity level on selenium accumulation in leaves and grain of spring wheat (*Triticum aestivum* L. cv. 'Yecora Rojo'). Plants were grown in greenhouse sand cultures and irrigated with complete nutrient solution. Salinity treatments were initiated 4 days after planting by irrigating the seedlings with either chloride-dominated waters or with waters containing both chloride and sulfate salts. Compositions of the mixed salt waters were designed to simulate saline drainage waters commonly present in the San Joaquin Valley of California. The experimental design was a randomized complete block with two salinity types (Cl^- or mixed salts), eight salinity levels (osmotic potentials = 0.07, 0 .16, 0.21, 0.30. 0.36, 0.44, 0.52, and 0.63 MPa), and three replications. Four weeks after planting, Se (1 mg L^{-1} as sodium selenate) was added to all irrigation waters. In the chloride system, the molar ratio of SO_4^{2-}:SeO_4^{2-} was approximately 110 across all salinity levels, whereas in the mixed salt system, the SO_4^{2-}:SeO_4^{2-} ratio in solution increased from about 300 to 4700 as salinity increased. Selenium concentration was determined in fully-expanded flag leaf blades and grain. Salinity type, and to a lesser extent, salinity affected Se accumulation. In the Cl^--system, wheat accumulated Se to levels that may be potentially harmful to livestock and humans, e. g. blade-Se ranged from 435 to 295 mg kg^{-1} dry wt; grain-Se ranged from 81 to 54 mg kg^{-1} dry wt. Under the saline conditions of the mixed salt system, the inhibition of selenium uptake by sulfate reduced both blade- and grain-Se to levels that would minimize the health risk to consumers.

J. Plant Nutrition, 22:1443-1450, 1999.

WHEAT RESPONSE TO INTERACTIVE EFFECTS OF BORON AND SALINITY

C.M. Grieve and J.A. Poss

In semiarid regions with irrigated agriculture, excess boron (B) often occurs in association with moderate to high salinity. However, little information is available on plant uptake of B under saline conditions. This greenhouse study was conducted to determine the interactive effects of salinity and varying concentrations of boron on growth, yield and ion relations of wheat *(Triticum aestivum* L., cv. 'Yecora Rojo'). Plants were grown in sand cultures that were irrigated four times daily with modified Hoagland's nutrient solution. Sixteen treatments were initiated 4 d after planting in a completely randomized factorial experiment with 4 salinity levels (electrical conductivities of the irrigation waters = 1.5, 4, 8, and 12 dS m^{-1}) and 4 B concentrations (1, 5, 10, and 15 mg L^{-1}). Salinizing salts were NaCl and $CaCl_2$ (2:1 molar basis). Symptoms of B toxicity were closely correlated with B concentration in the leaves and injury became severe when leaf-B exceeded 400 mg kg^{-1}. At each concentration of external B, shoot-B was least under nonsaline conditions and increased significantly as salinity increased. Shoot-calcium (Ca) concentration increased with increasing salinity, but was unaffected by applied B. Shoot-magnesium (mg), and potassium (-K) decreased significantly in response to increases in salinity and substrate B. Salinity and B as well as their combined effects significantly reduced wheat biomass production, yield components, and final grain yield.

J. Plant Nutr. 23: 1217-1226, 2000.

SALT TOLERANCE OF VEGETABLES

C.M. Grieve

In the near future, the challenge to growers, irrigation specialists, and horticultural scientists will be to maintain the high quality and wide variety of vegetables presently available to consumers in spite of constraints on fresh water supplies. High quality irrigation waters allocated for agriculture are threatened by increased competition from urban users. As an alternative, strategies for on-farm reuse of saline drainage water are under development, particularly in those areas that lack sufficient drainage outlets. Vegetable crops are, in general, moderately sensitive to salinity. A notable exception is asparagus (*Asparagus officinalis* L.) which is rated as the most salt tolerant vegetable crop. Other moderately salt tolerant crops are Swiss chard and garden beet (*Beta vulgaris* L.), turnip greens (*Brassica rapa* L. Rapifera Group), and purslane (*Portulaca oleracea* L.). Salinity-related nutritional disorders may result in cause leaf damage that reduce quality and marketability.. Vegetable species have a reasonable capacity for high growth under low to moderate saline conditions. If, however, these crops are to have market potential, irrigation practices must be closely managed to control soil salinity within acceptable levels.

Irrigation J. 50:28-30, 2000.

EFFECT OF SALINE IRRIGATION WATER COMPOSITION ON GROWTH, SHOOT ION RELATIONS AND SELENIUM UPTAKE BY *LESQUERELLA FENDLERI* (GRAY) S. WATS

C.M. Grieve, J.A. Poss, D.L. Suarez and D.A. Dierig

This study was conducted at the U.S. Salinity Laboratory, Riverside, CA to compare the response of lesquerella to irrigations waters differing in composition, namely, Cl-dominated salinity ($NaCl$:$CaCl_2$, 2:1 molar ratio), and mixed slat salinity (Na, So_4, Mg, and Cl as the predominant ions). The Cl-system has been used extensively in evaluation of salt tolerance of various crops, whereas the mixed salt-system is typical of saline drainage waters commonly encountered in the San Joaquin Valley of California. A further objective of the study was to determine the uptake of selenium by lesquerella irrigated with saline waters contaminated with this potentially toxic trace element.

Lesquerella was direct-seeded in 24 greenhouse sand tanks and irrigated with complete solutions. Salinity was imposed one month after planting; twelve tanks were irrigated with Cl-based waters and 12 with mixed salt salinity. The solutions were isoosmotic at each salt level: 0.070, 016, 0.30 and 0.52 MPa, with electrical conductivities (EC_i) of approximately 1.7, 4.8 and 12 dS•m^{-1}, respectively. One month later, selenium (1 mg•L^{-1}, 12.7 µM) was added to all solutions as Na_2SeO_4.

Regardless of salinity type, shoot biomass production was not significantly reduced until EC_i exceeded 8 d dS•m^{-1}. At 12 dS•m^{-1}, shoot dry weight decreased 60% in response to chloride-salinity and 40% in the mixed salt system.

Leaf tissue contained higher concentrations of Ca, Mg, Cl, S, and Se, than the stems; whereas concentrations of the monovalent cations, Na and K were higher in the stems than the leaves. Salt-stressed lesquerella shoots contained relatively low concentrations of Na and K compared to other cruciferous plants. In both salinity systems, the calcicolous nature of lesquerella was expressed by strong accumulation of Ca by both leaves and stems.

Selenium accumulation by lesquerella shoots was strongly influenced by the composition of the external media. In response to irrigation with Cl-dominated solutions, leaf-Se (mean = 500 mg•kg^{-1}) tended to decrease with increasing salinity, but this effect was not statistically significant. In contrast, the competitive inhibition of Se uptake by increasing concentrations of SO_4 was evident in lesquerella irrigated with waters prepared to simulate San Joaquin Valley drainage effluents. Leaf-Se decreased from 220 to 13 mg•kg^{-1} as in salinity increased from 1.7 to 12 dS•m^{-1}. Based on these preliminary results, lesquerella should be further evaluated as a potentially useful crop for the phytoremediation of Se-contaminated saline soils particularly in those systems where the dominant anion is Cl.

Proc. Assoc. Advancement Ind. Crops, "Diversity in Agricultural Products: New Crops and New Markets, Eugene, OR., Abstr. Pg. 28, Oct. 17-21, 1999.

SALINITY AND IRRIGATION METHOD AFFECT MINERAL ION RELATIONS IN SOYBEANS

C. M. Grieve, D. Wang and M.C. Shannon

Soybean (*Glycine max* (L.) Merrill) is moderately salt tolerant, but the method of irrigation used for crop production under saline conditions may influence the uptake of potentially toxic salts. This field study was conducted to determine the effects of application of saline waters by drip or above-canopy sprinkler irrigation on ion relations of the soybean cultivar 'Manokin'. Salinity was imposed by adding NaCl and $CaCl_2$ to nonsaline irrigation waters. Saline treatments with electrical conductivities (EC_i) of 4 $dS{\cdot}m^{-1}$ were compared with nonsaline controls (EC_i = 0.5 $dS{\cdot}m^{-1}$). Ion concentrations in leaves, stems, roots, and, when present, pods were determined at four stages of growth: vegetative, flowering, podding, and grain filling. In response to saline drip irrigation, Na^+ and Cl^- were retained in the basal parts of the plant with only limited partitioning of these ions to the leaves. Leaf-Na and -Cl concentrations in plants drip irrigated with saline water were 3 and 28 $mmol{\cdot}kg^{-1}$, respectively, at the grain-filling stage. When saline water was applied by over-canopy sprinkling, concentrations of Na^+ and Cl^- in the leaves were about 9-fold higher than in plants under saline drip irrigation. Regardless of treatment, leaf-K was highest during the vegetative stage of development, and then decreased with plant age as K^+ was mobilized to meet the nutrient demands of the developing reproductive structures.

Agronomy Abstract p. 116, 2000.

DETECTION OF *E. COLI* 0157:H7 IN ENVIRONMENTAL SAMPLES

A.M. Ibekwe and M.C. Shannon

Enteric infections due to food-borne bacterial pathogens account for annual losses of 3.5 billion dollars in the US. Detection of *Escherichia coli* 0157:H7 and other enterohemorrhagic serotypes (EHEC) in environmental samples is particularly challenging. *Escherichia coli* 0157:H7 is commonly carried by healthy cattle and shed in their feces. Cross-contamination of fruits and vegetables with manure or improperly composted manure are potential sources of pathogen contamination during pre-harvest. In this study we developed and evaluated the use of multiplex PCR method that rapidly detects EHEC 0157:H7 in environmental samples. Animal manure collected from a commercial dairy operation were inoculated with the pathogen and cultured in a modified-GN broth overnight. DNA was extracted and used in a multiplex PCR assay to amplify a 150 bp fragment of the virulence genes eaeA of EHEC 0157-H7. With this method we detected 10 to 100 cfu of EHEC after overnight growth in a single enrichment.

Agronomy Abstract p. 398, 2000.

CARBON ISOTOPE DISCRIMINATION AND TRANSPIRATION EFFICIENCY IN EUCALYPTUS UNDER SALINITY AND BORON STRESS

J.A. Poss, S.R. Grattan, D.L. Suarez, C.M. Grieve and M.C. Shannon

We tested the hypothesis that stable carbon-isotopic composition in Eucalyptus trees can be an indicator of the cumulative salinity and boron stress history of the plant. In a controlled, outdoor sand-tank study, Eucalyptus camaldulensis saplings were irrigated with combinations of salinity (EC 2 to 28 dS m-1) and B (1 to 30 mg l-1) to determine their influence on tree growth, water use, and stable carbon-isotope discrimination. Our results indicate carbon-isotope discrimination (D) was primarily reduced by salinity stress, whereas boron effects were smaller in magnitude and significant only at low salinity. Carbon-isotopic discrimination in leaves of Eucalyptus varied with position in the canopy. For example, proximal leaves sampled low in the canopy D decreased from 23.6 ‰ at low salinity (2 dS m-1 and 1 mg l-1 B) to 22.6 ‰ at high salinity (22 dS m-1 and 1 mg l-1 B). In distal leaves sampled high in the canopy, D decreased from 21.1‰ to 19.8‰ in corresponding treatments. Isotopic discrimination in woody tissue from tree trunks also correlated well with salinity stress. Moreover we found the relationship between D and EC of the irrigation water was similar to that of biomass and EC suggesting that D may be useful in describing salt tolerance in as well as quantifying the salt-stress history in C3 trees. There was a significant relationship between isotope discrimination in leaf and wood tissue with transpiration efficiency. The relationship was position sensitive for leaves and correlations with wood tissue increased with time under stress.

Proc. 3rd Int. Symp.on Irrigation of Horticultural Crops, Int. Soc. Hort. Sci., Lisbon, Portugal, Jun 28 - Jul 2, 1999.

STABLE CARBON ISOTOPE DISCRIMINATION: AN INDICATOR OF CUMULATIVE SALINITY AND BORON STRESS IN *EUCALYPTUS CAMALDULENSIS*

J.A. Poss, S.R. Grattan, D.L. Suarez and C.M. Grieve

Saplings of *Eucalyptus camaldulensis* Dehn. Clone 4544, irrigated with water of differing salinities (2 to 28 dS m^{-1}) and boron concentrations (1 to 30 mg m^{-1}), integrated the history of these stresses through the discrimination of stable isotopes of carbon in leaf and woody tissue. Carbon isotope discrimination (Δ) was reduced primarily by salinity. Decreases in discrimination in response to boron stress were detected in the absence of salinity stress, but the decreases were significant only in leaf tissues with visible boron injury. Sapwood core samples indicated that salinity- and boron-induced reductions in Δ increased with increasing tree age. Absolute values of Δ varied with location of leaf or wood tissue, but relative effects of salinity on the relationship between Δ and transpiration efficiency (W) were similar. In response to increasing salinity stress, relative decreases in Δ paralleled relative decreases in biomass and both indices yielded similar salt tolerance model parameters. The strong correlations between Δ, tree fresh weight, leaf area and W suggest that Δ is a useful parameter for evaluating salt tolerance of eucalypts.

Tree Physiol. 20:1121-1127, 2000.

PISTACHIO ROOTSTOCKS INFLUENCE SCION GROWTH IN PRESENCE OF MIXED SALINITY AND MODERATE BORON

J.A. Poss, C.M. Grieve, D. Wang, C. Wilson and T.J. Donovan

The salt tolerance of pistachio trees (*P. vera*) grafted on three rootstocks of pistachio (*Pistacia integerrima, P. atlantica,* and a *P. atlantica* x *P. integerrima* hybrid (UCB-1) was evaluated. Three trees were planted in each of 24 outdoor sand-tank lysimeters and irrigated with saline water containing 10 mg L-1 B. Four salinity treatments (3.5, 8.7, 12 and 16 dS/m in soil water) replicated six times were imposed for six months. Results were evaluated based on shoot biomass, canopy height, number of leaves, leaf area, injured leaf area, trunk diameter, transpiration, stomatal conductance, and SPAD value. The salt tolerance ranking was the same regardless of the growth parameter increase relative to the control trunk resulted in a salt tolerance ranking of *P. atlantica* (15.2 dS/m) = UCB-1 (16.3 dS/m) > *P. integerrima* (12.9 dS/m). Reduced SPAD meter values related to lower concentrations of chlorophyll for *P. integerrima* were associated with a greater degree offoliar injury with this rootstock.

Agronomy Abstract p. 116, 2000.

TOLERANCE OF HYBRID POPLAR (*POPULUS*) TREES IRRIGATED WITH VARIED LEVELS OF SALT, SELENIUM, AND BORON

M.C. Shannon, G.S. Bañuelos, J.H. Draper, H. Ajwa, J. Jordahl and L. Licht

Agricultural drainage waters and industrial effluents often consist of waste waters laden with salts, boron (B), selenium (Se), molybdenum (Mo), and other contaminants. However, increasing shortages of high-quality water in arid and semiarid regions and increasing demands to maintain the water quality in rivers, lakes, streams, and groundwater have made water reuse an imperative. Trees have been viewed as potential candidates for wastewater reuse because of their capacities for high evapotranspiration, high growth rates, and abilities to accumulate salts and specific ions in a marketable product that is not biologically hazardous. Clones of eight hybrid poplar (*Populus* spp.) crosses were tested for salt tolerance and ion uptake characteristics in a sand culture study in Riverside, CA. After hardwood cuttings were planted and established under nonsaline conditions, young saplings were treated with artificial waste waters containing different levels of salts, Se, and B. High salt concentrations reduced growth and led to leaf damage and shedding; however, Se and B had no detrimental effect on growth. Salinity affected Se and B accumulation patterns in leaves. A significant degree of genetic variation in salt tolerance was noted among the clones. The salinity at which dry weight was reduced ranged from about 3.3 to about 7.6 dS m^{-1} depending on clone, and the relative decrease in dry weight yield with increasing salinity varied among clones and ranged from about 10 to 15% per dS m^{-1}. This would indicate that poplars, whereas certainly more salt tolerant than avocado trees, are significantly less salt tolerant than eucalyptus. Leaf Cl concentrations increased in relation to the Cl concentrations in the irrigation waters, but also were subject to clonal variation. Salt tolerance in poplar was generally related to Cl in the leaves and stems but was also influenced by growth and vigor characteristics, as well as the allometric relationships between leaves and stems that influenced the sinks in which ions could accumulate before reaching toxic levels.

Int. J. Phytoremediation 1:273-288, 1999.

PHYTOEXTRACTION AND ACCUMULATION OF BORON AND SELENIUM BY POPLAR (*POPULUS*) HYBRID CLONES

G.S. Bañuelos, M.C. Shannon, H. Ajwa, J.H. Draper, J. Jordahl and L. Licht

There as been much interest recently in central California for reusing drainage water to grow trees. A sand-culture study was conducted to investigate the accumulation of boron (B) and selenium (Se) in eight hybrid poplar (*Populus*) clones irrigated with synthetic agricultural effluent containing increasing levels of chloride salt, B, and Se. Electrical conductivity (EC) ranged from 1.5 to 15 dS m^{-1}, B levels from 1 to 5 mg L^{-1}, and Se levels from 100 to 500 µg L^{-1}. Compared with all tree organs, the leaves accumulated the greatest concentrations of B and Se at the time of harvest. The results show that pooled leaf B concentrations were positively correlated with EC levels ($r=0.78$, $P<0.001$) and negatively correlated ($r=-0.53$, $P<0.001$) with leaf dry matter for all clones at all tested B levels. Combined leaf and stem Se data show, respectively, a significant decrease ($P<0.05$ level) in tissue accumulation of Se with increased salinity. Toxicity symptoms (e.g., burning leaf margins, shoot die back) occurred in most clones grown at 12 and 15 dS m^{-1} treatments leading to leaf abscission. Based on the data, clone 49177 (*Populus trichocarpa* x *P. deltoidus*) best tolerated the tested parameters among the clones and accumulated the greatest amount of B and Se. The moderate ability of the Populus species to remove and accumulate B and Se from saline effluent is most effective at salinity levels less than 7 dS m^{-1}.

Int. J. Phytoremediation, vol. 1:(1), 81-96, 1999.

OPTIONS FOR USING LOW-QUALITY WATER FOR VEGETABLE CROPS

M.C. Shannon and C.M. Grieve

At least two factors have led to increased interest in using low-quality, high-salinity water to grow crops. The first is the lack of drainage outlets in many agricultural areas of the world. In order to avoid lowering water quality for downstream users, regulations have evolved that mandate on-farm or regional strategies for reuse and/or disposal of saline drainage water. A second factor is that competition between agricultural and urban users for high-quality water has increased as the population has increased. Thus, agricultural users must rely more on low-quality water resources. Traditionally, growers have shifted from salt-sensitive crops to more tolerant species in order to avoid yield losses associated with high salinity. Usually this involves changing from crops of higher cash value to crops of lower value. Vegetable crops are generally less salt-tolerant and have higher cash value than most field and grain crops. Germplasm and management practices need to be improved to provide the grower with more economical and environmentally acceptable options for drainage water reuse. Some investigators have suggested that low-quality and high-quality waters can be used in successive applications during crop rotations or even within a rotation, if applied during growth stages that are more salt-tolerant or salt-sensitive, respectively. The addition of saline water during fruiting of melon (*Cucumis melo* L.) and tomato (*Lycopersicon esculentum* Mill.) has even been found to enhance sugar and soluble solid contents and to improve flavor and market price. Although much research is needed to quantitatively define salt-tolerant and salt-sensitive growth stages for vegetables, the potential high cash value of vegetable crops would go far in offsetting the costs of drainage and water delivery systems necessary to implement water reuse practices. Vegetable crops that may be grown using the cyclic water-use strategies may include both traditional and potentially new species.

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ANALYSIS OF SALT TOLERANCE IN NINE LEAFY VEGETABLE SPECIES IRRIGATED WITH SALINE DRAINAGE WATER

M.C. Shannon, C.M. Grieve, S.M. Lesch and J.H. Draper

Saline agricultural drainage water may be used as a resource to grow high value horticultural crops and reduce the volume of drainage for eventual disposal. To explore reuse options the effects of salinity and timing of application were tested on nine vegetable species grown in 24 sand culture plots in Riverside, California. The leafy winter vegetables that were tested included spinach (*Spinach oleracea*, L.), greens (*Brassica rapa*), red giant greens (*Brassica juncea*), Swiss chard (*Beta vulgaris*), kale (*Brassica oleraceae*), pac choi (*Brassica rapa*), tatsoi (*Brassica rapa*), radicchio (*Cichorium intybus*), and endive (*Cichorium endivia*). All vegetables were planted at the same time and initially irrigated with tap water and nutrients having an electrical conductivity of about 3 dS m^{-1}. At three and seven weeks salinity treatments were initiated by adding salts to the irrigation water made to the chemical compositions of drainage waters typically found n the San Joaquin Valley, CA. Electrical conductivities of the six salinity treatments were 3 (control), 7, 11, 15, 19 and 23 dS m^{-1}. A randomized complete block design was used (6 salinities x 2 application times x 2 replications) and within each plot a 1.5 m row of the nine vegetables were grown as split plots. A random sample of three plants per species was harvested for fresh and dry weight analyses and a statistical modeling approach was developed to analyze the effects of salinity and application time on each vegetable. Salinity reduced fresh weight yields of all species and salination at three weeks further reduced fresh weights in seven of the nine compared to salination at seven weeks. An analysis of salt tolerance curves, maximum yields, and the point of 50 percent yield reduction (C_{50}) was made. Greens produced the highest biomass at 874 g per plant but was the most affected by salination time. Chard and radicchio were not significantly affected by timing of salination and chard was the most salt tolerant overall. Red giant greens, kale, pac choi, greens, and to a lesser extent, tatsoi, could all have potential as winter-grown, leafy vegetables in drainage water reuse systems.

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SINGLE CYCLE SELECTION FOR SALT TOLERANCE IN *LESQUERELLA FENDLERI* (GRAY) S. WATS

M.C. Shannon, D.A. Dierig, C.M. Grieve and J.H. Draper

In a study conducted in 1997-1998, to determine the salt tolerance of *Lesquerella fendleri* (Gray) S. Wats., it was found that saline irrigation above 21 dS/m electrical conductivity resulted in high plant mortality. Replicate Plots having a combined population of 216 plants yielded only five surviving plants at 24 dS/m and 13 survivors at 21 dS/m. In an effort to determine if *Lesquerella* had heritable characters for salt tolerance, surviving plants were inter-mated under controlled conditions and seed was collected from these plants. The following season, on 28 Oct. 1998, seed of the selected salt tolerant full-sibs, designated line 'C', were direct seeded along with two other lines for comparison in a replicated randomized block salinity trial conducted in 21 outdoor sand tanks. Line 'A' was the original seed planted the previous year, and line 'B' was a check line. After seeding,, the tanks were irrigated daily with complete nutrient solutions. Plant populations were thinned to 24 plants/line/plot on 21 Jan. 1999, and salinity was imposed by stepwise additions of mixed salt salinity composed predominantly of Na, Mg, SO_4, and Cl ions. Over a period of one week, salinity levels in the tanks were increased to 3, 7, 11, 15, 18, 21, and 24 dS/m, with three replications.

Plants were counted and plant heights were measured weekly. At the time of salinization C-line plants were already significantly taller than B- and A-line plants in all plots, 11.7, 6.62, and 4.09 cm, respectively. Within two weeks after salinization significant treatment differences in both plant height and survival were observed among lines due to salinity stress. Plant survival decreased as a function of time and salinity concentration. The parental line A was most sensitive, C-line most tolerant and B-line intermediate. By 25 Feb. none of the A-line plants survived at the 24 dS/m salinity level. Plants were harvested on 15 Jun. and individual dry weights of plants and seed were recorded. Seed was saved for analysis of oil quality. Leaf samples were taken, dried, ground, and weighed to measure ion content.

Analysis of the final shoot dry weights indicated that salinity and line effects were significant but there was no interaction. Salinity decreased average shoot dry weights in all lines as a function of increasing salinity and ranked mean differences within lines were consistent across all salinity levels from 3 to 18 dS/m. At 7, 15, and 18 dS/m average shoot dry weights of the C-line was significantly greater than the parental A-line. The average mean shoo9t weight of B-line was intermediate but always lower than C-line. Our results showed that across all salinity levels, the C-line had higher average shoot dry weights (25.9 g/plant) than either the B-line (17.4 g/plant) or the A-line (11.2 g/plant). Our results indicate that a single cycle selection of Lesquerella in salinized sand cultures resulted in a C-line that had higher absolute and relative salt tolerance as measured by shoot dry matter production, plant height and plant survival. Selected, surviving, C-line plants in the 18, 21 and 24 dS/m plots were either crossed or selfed to provided future information on the inheritance of the salt tolerance character.

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SINGLE CYCLE SELECTION FOR SALT TOLERANCE IN LESQUERELLA

M.C. Shannon, D.A. Dierig, J.H. Draper and C.M. Grieve

A previous salinity study resulted in high mortality in *Lesquerella fendleri* above 21 dS/m electrical conductivity. Surviving plants were inter-mated to determine if Lesquerella had heritable characters for salt tolerance. Seed of the selected full-sibs, line ‘C’, were direct seeded with two other check lines in a salinity trial conducted in 21 outdoor sand tanks. Salinity was imposed by stepwise additions of mixed salts in irrigation solutions composed of Na, Mg, SO_4, and Cl ions to 3, 7, 11, 15, 18, 21, and 24 dS/m, with three replications. Plant survival decreased with time and salinity but seed oil increased. None of the A-line checks survived at 24 dS/m. Average shoot dry weights decreased in all lines with increasing salinity and ranked meant differences within lines were consistent across all salinities to 18 dS/m. At 7, 15, and 18 dS/m average shoot dry weights of the C-line was significantly greater than the A-line. Average shoot weight of the B-line was intermediate. Across all salinity levels, the C-line had higher average shoot dry weight than either B- or A-line, 25.9, 17.4, and 11.2 g/plant, respectively. Thus, a single cycle selection of Lesquerella resulted in a C-line that had higher absolute and relative salt tolerance as measured by shoot dry matter production, plant height, and plant survival.

Agronomy Abstract p. 112, 2000.

USE OF RECYCLED DRAINAGE WATER ON THREE SALT-TOLERANT, WARM-SEASON GRASSES

M.C. Shannon, J.D. Oster and T.J. Donovan

Drainage water reuse is an important option for the reduction of drainage water volume. Three warm-season grass species were tested for salt tolerance and water use in sand cultures using simulated saline drainage waters. Bermuda grass (*Cynodon dactylon*), silt grass (*Paspalum vaginatum*) and salt grass (*Distichlis spicata*, var NyPa). Saline irrigations were composed of Ca, Na, Mg, SO_4, and Cl made to solution electrical conductivities of about 6, 10, 16, 24, and 30 dS/m, with the nonsalinized control at 2 dS/m. In 1997, highest yield of silt grass was better than salt grass and Bermuda grass (2106, 1477, and 1410 g/m^2 dry weight, respectively. In 1998, salinities were increased to 6, 10, 16, 20, 30, and 45 dS/m. Maximum yields of silt grass (2112 g/m$^{2)}$ were obtained at 10 dS/m. Maximum yield of Bermuda grass (2014/g/m^2) and salt grass (1432 g/m^2) were obtained at 16 dS/m. Salinity increase ash content and significantly reduced digestible fiber content (ADF and NDF). Increasing salinity generally decreased Ca and K contents of shoots and increased Na and Cl.

Agronomy Abstract p. 179, 2000.

EMERGENCE AND SEEDLING GROWTH OF SOYBEAN CULTIVARS AND MATURITY GROUPS UNDER SALINITY

D. Wang and M.C. Shannon

Soybean is an important agricultural crop and has, among its genotypes, a relatively wide variation in salt tolerance. As measured by vegetative growth and yield, however, the achievement or failure of a high emergence ratio and seedling establishment in saline soils can have significant economic implications in areas where soil salinity is a potential problem for soybean. This study was conducted to determine the effects of salinity, variety and maturation rate on soybean emergence and seedling growth. Included in the study were the variety 'Manokin'; four near-isogenic sibling lines of the variety 'Lee' belonging to maturity groups IV, V, VI and VII; and the variety 'Essex' and two of its near-isogenic related lines representing maturity groups V, VI and VII, respectively. Field plots were salinized with sodium chloride and calcium chloride salts prior to planting. The soybeans were irrigated with furrow irrigation which redistributed the salts towards the tail ends of the field plots. Elevated soil salinity near the tail ends of the field significantly reduced soybean emergency rate, shoot height and root length. No significant reduction was found for emergence or seedling growth of variety 'Manokin' when the electrical conductivity of soil solution extract (ECe) was less than 3 dS m^{-1}. Soybean emergence and seedling growth was significantly reduced when soil ECe reached about 11 dS m^{-1}. Maturity groups V and VII of variety 'Lee' or V and VI of 'Essex' appeared to be more sensitive to salinity stress than other maturity groups. Salt tolerance of different genotypes and maturity groups should be considered, among other limiting factors, in minimizing salinity effects on soybean growth.

Plant and Soil, 214:117-124, 1999.

SOIL WATER AND TEMPERATURE REGIMES IN DRIP AND SPRINKLER IRRIGATION, AND IMPLICATIONS TO SOYBEAN EMERGENCE

D. Wang, M.C. Shannon, C.M. Grieve and S.R. Yates

Irrigation has long been used in agriculture as a primary means of water management. It is well known that water distributions in the soil differ depending on the methods of irrigation. However, it is less clear how soil thermal regimes would change over time and space when irrigation methods are different. A field study was conducted to investigate the interactive effect of soil water and temperature regimes in drip and sprinkler irrigation. The effect of different methods of irrigation on soil water and thermal environment was then used to interpret differences in soybean emergence and seedling growth under the two irrigation treatments. Time domain reflectometry wave-guides and thermocouples were installed in field plots to provide soil water content and temperature measurements. Soybean seeds were planted to assess the emergence and seedling development. Consistent with infiltration theory, soil water contents were higher directly under the drip tapes in drip irrigation, but were relatively more uniform across the whole soil surface in sprinkler irrigation. Although five times more water was used in the sprinkler than in the drip plot, the soil water content at the seed zone was similar. Soil temperature was significantly higher in the drip than in the sprinkler plot, which led to a higher emergence rate and enhanced seedling growth. Drip irrigation not only conserved water but also maintained the soil profile at a higher temperature more favorable for plant emergence and seedling development.

Agric. Water Management 43:15-28, 2000.

SOYBEAN CANOPY REFLECTANCE UNDER DIFFERENT SALINITY AND IRRIGATION TREATMENTS

D. Wang, C. Wilson and M.C. Shannon

High levels of soil and water salinity can strongly decrease plant growth rate, reducing yield and quality in agricultural and horticultural crops. Effects of salinity may be determined by measuring reflectance characteristics of plant canopies before final yield reduction occurs. Spectral reflectance of the soybean canopy was measured over time using a hand-held multispectral radiometer. To relate the reflectance with salinity and irrigation effects, leaf chlorophyll contents were determined from chlorophyll concentrations measured with a Minolta SPAD-502 meter and leaf areas measured from destructive plant samples. For soybeans grown under salinity, canopy reflectance in the 810 to 950 nm or NIR spectrum region was about10% lower than plants not treated with salinity, regardless of the irrigation method employed. The reflectance decrease in NIR and a small increase in the red spectrum region resulted in reductions in calculated normalized difference vegetation index or NDVI. The reflectance increase in the red spectrum region was due to losses of chlorophyll from salinity stress. The critical time to detect salinity effects by reflectance measurements was near the end of plant vegetative growth phase before maturation and senescence had begun.

Agronomy Abstract p. 16, 1999.

SALINITY DISTRIBUTION UNDER DRIP AND SPRINKLER IRRIGATION AND EFFECTS ON SOYBEAN GROWTH

D. Wang, M.C. Shannon, T.J. Donovan and C.M. Grieve

Crop salt tolerance research traditionally reports crop yield response on the basis of average root-zone soil salinity. Soil salinity, however, is seldom uniform; the spatial and temporal distributions of soil salinity under field conditions are highly dynamic, and are functions of irrigation and plant water extraction. This study was conducted to determine the characteristics of salinity distribution under different irrigation regimes and to correlate these distributions with soybean growth parameters. Salinity effects were imposed by irrigation with salinized water (NaCl and $CaCl_2$, 1:1 by weight). Detailed soil salinity and water content measurements were obtained with time-domain reflectometry over time and space. Measured soybean growth parameters were plant height, root length, biomass accumulation of plant shoot and root, and leaf area. Results indicated that the spatial and temporal distributions of soil salinity were different depending on the methods, amount, and salinity levels of the irrigation. More salt accumulation was found in the soil profile in the drip than in the sprinkler irrigation plot. Drip irrigation created a region of high soil salinity in the 20 to 30 cm depth range which limited root penetration. Salinity and irrigation treatment resulted in water stress and reduced soybean shoot development.

Agronomy Abstract p. 283, 1999.

SOIL WATER AND TEMPERATURE REGIMES IN A SAND CULTURE FOR SCREENING PLANT SALT TOLERANCE

D. Wang, T.J. Donovan and M.C. Shannon

Because of the high spatial and temporal variability in soil salinity under field conditions, plant salt tolerance studies are often conducted in greenhouse sand cultures for better salinity control. This study was conducted to determine soil water and temperature regimes in the sand cultures and to compare with a field soil. Results indicated that sand cultures with well-graded texture, such as the washed river sand, can provide water and thermal regimes comparable to a field soil. If other environmental factors for the plant growth can be simulated to match that in field conditions, results of plant salt tolerance obtained from the sand cultures can be used to provide guidance for plant selection under field conditions. A more realistic approach for salt tolerance studies in the sand cultures is to create a set of sand media with gradual salinity changes over time and space simulating soils of different textures such as loamy sand, silt loam, or clay.

Agronomy Abstract p. 201, 2000.

GROWTH STAGE MODULATES SALINITY TOLERANCE OF NEW ZEALAND SPINACH (*Tetragonia tetragonioides,* pALL.) AND RED ORACH (*Atriplex hortensis* L.)

C. Wilson, S.M. Lesch and C.M. Grieve

The response of two speciality vegetable crops, New Zealand spinach (*Tetragonia tetragonioides* Pall.) and red orach (*Atriplex hortensis* L.), to salt application at three growth stages was investigated. Plants were grown with a base nutrient solution in outdoor sand cultures and salinized at 13 (early), 25 (mid), and 42 (late) d after planting (DAP). For the treatment salt concentrations, we used a salinity composition that would occur in a typical soil in the San Joaquin Valley of California using drainage waters for irrigation. Salinity treatments measuring electrical conductivities (EC_i) of 3, 7, 11, 15, 19 and 23 dS m^{-1} were achieved by adding $MgSO_4$, Na_2SO_4, NaCl and $CaCl_2$ to the base nutrient solution. These salts were added to the base nutrient solution incrementally over a 5-d period to avoid osmotic shock to the seedlings. The base nutrient solution without added salts served as the non-saline control (3 dS m^{-1}). Solution pH was uncontrolled and ranged from 7•7 to 8•0. Both species were salt sensitive at the early seedling stage and became more salt tolerant as time to salinization increased. For New Zealand spinach, the salinity levels that gave maximal yields (C_{max}) were 0, 0 and 3•1 dS m^{-1} and those resulting in a 50% reduction of biomass production (C_{50}) were 9•1, 11•1 and 17•4 dS m^{-1} for early, mid and late salinization dates, respectively. Maximal yield of red orach increased from 4•2 to 10•9 to 13•7 dS m^{-1} as the time of salinization increased from 13, to 26, to 42 DAP, respectively. The C_{50} value for red orach was unaffected by time of salt imposition (25 dS m^{-1}). Both species exhibited high Na^+ accumulation even at low salinity levels. Examination of K-Na selectivity data indicated that K^+ selectivity increased in both species with increasing salinity. However, increased K-Na selectivity did not explain the increased salt tolerance observed by later salinization. Higher Na-Ca selectivity was determined at 3 dS m^{-1} in New Zealand spinach plants treated with early- and mid-salinization plants relative to those exposed to late salinization. This corresponded with lower C_{max} and C_{50} values for those plants. Lower Ca uptake selectivity or lower Ca levels may have inhibited growth in young seedlings. This conclusion is supported by similar results with red orach. High Na-Ca selectivity found only in the early-salinization plants of red orach corresponded to the lower C_{max} values measured for those plants.

Annals of Bot. 85:501-509, 2000.

EFFECT OF SULFATE-BASED SALINITY ON GROWTH OF BARNYARDGRASS (*Echinochola crus-galli* L. Beauv.)

C. Wilson and J.J. Read

High-quality water needed for agriculture is becoming increasingly scarce due to changing environmental standards and rising demands from urban areas. Several irrigation schemes have been proposed to utilize higher salinity waters. However, growth under saline conditions could alter the competition between weeds and crops. Information on the effects of saline irrigation waters on weed growth is limited. In this study, we investigated the effect of sulfate-based salinity on the growth responses of a C4-weed, barnyardgrass. Barnyardgrass was harvested following 41 days of sanitization when most plants were at the jointing or booting stage of development. Previous reports on growth responses of crop plants to salinity were interpreted in terms of a linear two-piece model. Across the four salinity treatments, 3 (control), 7, 11, and 19 dS m^{-1} , our data on barnyardgrass were better described by a quadratic function. Data were analyzed using analysis of variance and general linear models in SAS. Values for fresh weigh per plant on dS m^{-1} indicated a highly significant ($P<0.002$) linear relationship. Fresh weight decreased significantly (F ratio = 6.53; $P<0.003$) as salinity increased, and was least at 19 dS m^{-1}. The linear salt tolerance model had a slope of -0.08 (SE = 0.02) and a C50 value of about 14.3 dS m^{-1}. Total-S, total-P, Ca^{+2}, Mg^{+2}, Na^{+}, and K^{+} in shoots were measured. The role of these ions in salinity tolerance will be discussed.

Weed Science Society of America Abstracts p. 49, 1999.

EFFECT OF EXOGENOUS POLYAMINES ON SPINACH GROWTH AND CARBOHYDRATE METABOLISM

C. Wilson, S. Suleiman and L. Zeng

Salt-induced suppression of crop yield is a major problem in irrigated areas. Polyamines, a new class of growth regulators, are thought to be involved in plant responses to stress. We investigated the effect of the exogenously supplied polyamines, putrescine, spermine, and spermadine, on spinach (*Spinacia oleracea* L, cv. Space) growth. In order to investigate the effect of salinity on growth mechanism(s), we examined photosynthesis and sugar (glucose, fructose, and sucrose) levels. Salinity significantly affected growth with decreased growth measured at the higher salinity levels. However, we did not observe any significant changes in photosynthesis with increasing salinity. Exogenously supplied polyamines had no measurable effect on salt-induced growth suppression. Increasing salinity did alter the diurnal pattern of sugar levels. While salinity decreased afternoon levels of glucose, it had no effect on morning levels. Conversely, morning levels of sucrose increased with increasing salinity while afternoon levels were not affected. We found no effect of salinity on fructose levels, regardless of time of day. Polyamines application did not affect this pattern. The relationship between salinity and diurnal carbohydrate metabolism will be discussed.

Agronomy Abstract p. 97, 1999.

SALINITY EFFECTS ON SEEDLING GROWTH AND YIELD COMPONENTS OF RICE

L. Zeng and M.C. Shannon

Flood irrigation practices that are commonly used in California during the early stages of rice (*Oryza sativa* L.) establishment may contribute to salinity damage and eventually decrease yield. Knowledge of salinity effects on rice seedling growth and yield components would improve management practices in fields and increase our understanding of salt tolerance mechanisms in rice. Salinity sensitivity of rice was studied to determine salinity effects on seedlings and yield components. Plants of rice cultivar M-202 were grown in a greenhouse in sand and irrigated with nutrient solutions of control and treatments amended with NaCl and $CaCl_2$ (2:1 molar concentration) at 1.9, 3.4, 4.5, 6.1, 7.9, and 11.5 dS m^{-1} electrical conductivity. Shoot dry weights of seedlings were measured at five harvests in the first month after seeding. Seedling growth was significantly reduced by salinity at the lowest salinity treatment, 1.9 dS m^{-1}. At 1.9 and 3.4 dS m^{-1}, significant reduction of seedling growth occurred at longer cumulative thermal time than at higher salt levels. Seedling survival was significantly reduced when salinity 3.40 dS m^{-1} and higher. Highly significant linear responses of grain weight per plant, grain weight per panicle, spikelet number per panicle, and tiller number per plant to salinity were observed. There was a common lowest salt level for fertility and pollen germination beyond which they were significantly reduced by salinity. Harvest index was significantly decreased when salinity was at 3.40 dS m^{-1} and higher. Tiller number per plant and spikelet number per panicle contributed the most variation in grain weight per plant under salinity. Reductions in seedling survival, tiller number per plant, and spikelet number per panicle were the major causes of yield loss in M-202 under salinity. The compensation between spikelets and other yield components was confounded with salinity effects, but was believed to be minor relative to the reduction of spikelets due to salinity and, therefore, not sufficient to offset yield loss even at moderate salt levels.

Crop Sci. 40:996-1003, 2000.

EFFECTS OF SALINITY ON GRAIN YIELD AND YIELD COMPONENTS OF RICE AT DIFFERENT SEEDING DENSITIES

L. Zeng and M.C. Shannon

Substantial loss of plant stand and yield reduction have been observed in salt-affected, direct water-seeded rice (*Oryza sativa* L.). One of the possible management options for growers in dealing with decreases in rice production caused by salinity is to compensate yield reduction due to loss of plant stand during early stages by increasing seeding density. The objectives of this study were to investigate the effects of salinity and seeding density on grain yield and yield components, and analyze the relationships of the yield components to final grain yields at different seeding densities under salinity. Plants were grown in the greenhouse in silica sand irrigated with nutrient solutions. The treatments included seeding densities of 400, 600 and 720 seeds m^{-2} and salt levels of 1.0, 3.9 and 6.5 dS m^{-1}. Yield components were measured on individual plants and grain yields were measured on an unit area basis. Salinity effects were highly significant on grain yield, plant stand, seed weight per plant, seed weight per panicle and spikelets per panicle at each seeding density, but not significant on panicle density and kernel weight. Grain yield was not significantly increased with an increase of seeding density. Plant stand and panicle density were significantly increased while seed weight per plant and fertility were significantly decreased with increases of seeding densities. Seed weight per panicle accounted for 63% of total variation and contributed more than panicle density to the grain yield under salinity. It was concluded that yield loss under moderate salinities may not be compensated by increasing seeding density above normal density levels. Other management options or new cultivars with improved salt-tolerance must be developed.

Agronomy J. 92:418-423, 2000.

TIMING OF SALINITY STRESS AFFECTS RICE GROWTH AND YIELD COMPONENTS

L. Zeng, M.C. Shannon and S.M. Lesch

The irrigation schemes in rice production have accelerated soil salinization processes and raised salt levels in standing water of rice fields in many regions. Substantial loss in plant stand and final yield reduction were observed in some salt-affected rice fields in California. Salinity problems in salt-affected rice fields might be relieved by developing appropriate management options for rice growers. Our previous studies have shown that increasing seeding density was not an effective method to ameliorate rice yield reduction under salinity. The development of other management options requires the analysis of sensitivity parameters which affect the interaction between salinity and crop yield. Timing of salinity stress is one such parameter which has rarely been reported. Plants were grown in silica sand irrigated with nutrient solutions in a greenhouse. Plants were salinized and stress was relieved at different growth stages. Plant shoot dry weight was analyzed at both seedling and mature stages. Yield components were analyzed at final harvest. The effects of salinity and timing were significant on plant growth and most yield components. Panicle initiation was identified as the most salt-sensitive stage affecting grain yield. The relationship between vegetative growth and final grain yield was also analyzed.

Agronomy Abstract p. 97, 1999.

EVALUATION OF SALT TOLERANCE IN RICE GENOTYPES BY MULTIPLE PARAMETERS

L. Zeng, M.C. Shannon, C.M. Grieve and J.A. Poss

This study was designed to identify the agronomic parameters contributing to salt tolerance in seed yield and evaluate genotypes of different sources on multiple parameters for salt tolerance. Plants were grown in a greenhouse in sand and irrigated with nutrient solutions of control and treatments amended with NaCl and $CaCl_2$. Wide genotypic differences in relative salt tolerance of seedling growth were identified among genotypes. Reproductive growth including panicle initiation and anthesis was delayed in all genotypes. Spikelet number per panicle, tiller number per plant, and seed weight per panicle were significantly reduced by salinity in most genotypes. Wide genotypic differences in relative salt tolerance of these yield components were identified among genotypes. No genotypic difference was identified for fertility and kernel wight among genotypes. The means of the salt tolerance indexes in the multiple parameters were analyzed simultaneously using a multivariate analysis. The genotypes were ranked for salt tolerance at different growth stages based on multivariate analysis. Spikelet number per panicle and tiller number per plant were suggested as a multiple selection criteria in the screening for salt tolerance.

Agronomy Abstract p.191, 2000